Twenty–Three Thinking Questions

Understanding Energy and Voltage

1. Draw the following systems:

**A:** Two objects of mass M and m are a distance R apart.

**B:** Two objects of mass M and m are twice as far apart as in system A.

1. Suppose the first system has a gravitational potential energy of -50J. What is the gravitational potential energy of the second system? Label each system with the gravitational potential energy.
2. Which system has a higher gravitational potential energy?
3. In general, if two masses are moved apart, does gravitational potential energy increase or decrease?

**C:** Two objects of charge +Q and -Q are a distance R apart.

**D:** Two objects of charge +Q and -Q are a distance 2R apart.

1. Is the electric potential energy of these systems positive or negative?
2. Label each system with arbitrary but appropriate values for electric potential energy.
3. In general, if two opposite charges are moved apart, does electrical potential energy increase or decrease?

**E:** Two objects of charge +Q and +Q are a distance R apart.

**F:** Two objects of charge +Q and +Q are a distance 2R apart.

1. Label each system with appropriate electric potential energy.
2. If two like charges are moved apart, does potential energy increase or decrease?
3. Refer to the drawings above to help you answer:
4. In an **attractive** system of charges or masses, how do you **increase** the potential energy of the system? When you release the charges/masses, where do they go?
5. In a **repulsive** system of charges, how do you **increase** the potential energy of the system? When you release the charges/masses, where do they go?
6. In **all** systems, the system will always naturally go from a state of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ potential energy to \_\_\_\_\_\_\_\_\_\_\_\_\_\_ potential energy.
7. How do you increase the gravitational potential energy of a book on a shelf?
8. How much is gravitational potential energy increased when a 2kg mass is moved from the ground to a height of 3m?
9. How can the potential energy in the previous question be put to work?
10. How much electrical potential energy is stored when a +4C charge is moved from a potential of 3V to a potential of 5V?
11. How can the potential energy in the previous question be put to work?
12. How much electrical potential energy is stored when a +3C charge is moved from a potential of -7V to +5V?
13. How much work is done when a -3C charge is moved from a potential of -7V to +5V?
14. What does it mean when we say that electrons “like to go uphill”?
15. How much work does it take to move a +5C charge from a potential of 3V to a potential of 3V? Draw a picture of how this can be done.
16. A satellite is in orbit at a certain altitude. Does the satellite need a rocket booster to maintain its altitude as it goes around?
17. A car is at the foot of a hill. There is a road around the bottom of the hill and a second road that goes up the hill and down the other side. Do both paths take the same energy? Explain.

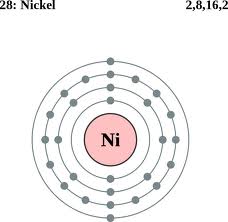
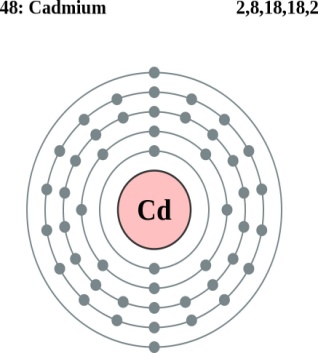
Understanding the Battery

1. What is the difference between a 9V battery and a 12V battery?
2. How much work can 5 Coulombs of charge do if they are released from a 12V battery?
3. A 9V battery sends charges through a motor to do some work. The motor is prepared to lift a 4kg mass. How much charge must enter the motor for it to lift the mass through a height of 5m?
4. A single electron has a charge of -1.6x10-19C. How many electrons are needed to do the work calculated in the previous question?
5. A battery has two terminals. An electron leaves the -3V terminal and passes through a circuit before ending up at the +3V terminal.
6. Why would the electron “want” to leave the terminal? Give two ways of answering this question.
7. How much energy does that electron lose when it passes through the circuit?
8. Where does the energy go?
9. A battery has two terminals. An electron leaves the -4V terminal and does 3.2x10-19J of work before arriving at the second terminal. What is the “voltage” of the second terminal?

Understanding the Atom

1. A hydrogen atom consists of a proton of charge +1.602x10 -19C and an electron (of the same charge, but negative). The electron is in an orbit of radius 5.1x10-11m about the proton.
2. What is the electric potential energy of the hydrogen atom?
3. The *ionization energy* is the energy required to remove the electron from the atom. What is the ionization energy of the hydrogen atom?
4. What is another term for ionization energy?
5. How much energy does it take for an electron in a hydrogen atom to jump from the first shell (radius 5.1x10-11m) to the second shell (1.2x10-10m)?

1. A helium atom consists of two protons and two electrons.
2. Draw a simple Bohr diagram of a helium atom.
3. Even though the helium atom has more “stuff” in it than a hydrogen atom, the helium atom has a smaller atomic radius. Why does this make sense?
4. A helium ion has one electron only. If the electron orbits at a radius of 3.0x10-11m, find the ionization energy of the helium ion.
5. Is it harder or easier to ionize a helium ion than a hydrogen atom?
6. A NiCd battery contains two metals: nickel and cadmium. Nickel has 28 electrons in 4 shells and cadmium has 48 electrons in 5 shells. Here are their simplified Bohr diagrams:

1. Which atom has a greater atomic radius?
2. Which atom would be easier to remove the outermost electron? Give two reasons.
3. If a battery were to consist of nickel at one terminal and cadmium at the other terminal, which terminal would be positive and which terminal would be negative? Explain.
4. Suppose the outermost shell of the nickel atom is at a potential of +3.0V and the outermost shell of the cadmium atom is at a potential of +1.8V. What would the voltage of a NiCd battery be?